INFLUENCE OF SUMMER MANAGEMENT PRACTICES OF GRAZED WHEAT PASTURES ON RUNOFF, SEDIMENT, AND NUTRIENT LOSSES

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ABSTRACT. *The agricultural economy of the southern Great Plains relies on practices that incorporate grazed winter wheat and associated summer management practices. Information exists about the impact of these practices on water quality, but data related to runoff and associated nutrient and sediment movement due to high intensity, late summer storms in the southern Great Plains are limited. This study examined runoff and runoff water quality from two winter wheat management strategies: winter wheat with summer chemical fallow (WWF) and winter wheat with summer legumes (WWSL) and two grazing treatments (grazed and ungrazed) from 1998 to 2002. Four pastures were planted in conservation winter wheat and grazed from November to May. Summer legumes were direct seeded in two of the pastures in March and grazed mid-July to September. Runoff from plots (1.5 × 3 m) was quantified with a rainfall simulator, with rainfall intensities representing a late summer, short duration (15 min), high intensity (10 cm/h) summer storm. Runoff samples were analyzed for nitrate-N (NO_3-N), bioavailable and water-soluble phosphorus (BAP and WSP, respectively), and sediment yield. Overall, the WWF practice had greater runoff, sediment, and nutrient losses than the WWSL strategy. Likewise, grazing produced greater runoff, sediment, and nutrient losses than ungrazed plots. The worst-case scenario was WWF pastures that incorporated winter grazing, with 71% of applied rainfall lost as runoff. The greatest losses for sediment (284 kg/ha), NO_3-N (124 kg/ha), BAP (380 g/ha), and WSP (38 g/ha) were found with the grazed WWF practice. Understanding the mechanism of interaction between late summer storms and summer management practices will improve large-scale mitigation strategies to reduce erosion and enhance capture of water resources.*

Keywords. *Legumes, Livestock grazing, Summer fallow, Winter wheat.*

Availability of water is a growing concern in the U.S., particularly in the central and western regions, and the demand for water will only grow with an ever-increasing population. A primary issue to be addressed is identifying ways to provide adequate supplies of potable water to maintain current lifestyles. This issue includes anticipating future water needs in large urban areas, while maintaining supplies for agricultural production. Agriculture is a major user of water, and agricultural practices are found to affect in-field and downstream conditions (USGS, 1999). While runoff impacts sediment movement, runoff can also be considered a water resource that is removed from a pasture, carried downstream, and thus lost to its agricultural application as it leaves a watershed or region (Daniel and Staricka, 2000). While there are downstream users that rely on runoff, enough water must remain behind, stored as soil water or ground water recharge, to maintain agricultural purposes.

A primary mainstay of the agricultural economy in the Southern Great Plains (SGP) is stocker calf production. Stocker calves are born and weaned in the southeastern U.S. and shipped west (fig. 1). Because of the proximity of feedlots, in which 85% of the nation's beef is finished, winter wheat grazing plays a major role in Oklahoma's economy and the nation's beef industry. Stocker production systems incorporate grazing of winter wheat for up to 180 days during the fall, winter, and spring (November through April). The system is also flexible enough to allow either extended grazing through May for harvesting beef (grazeout) or livestock removal for grain harvest (graze-grain) in early March. After the wheat has been grazed or harvested for grain, fields are typically left fallow during the summer. This fallow period allows soil water to accumulate for the next crop to be planted in fall. However, warm-season annual legumes have been planted in wheat fields for summer forage to extend the grazing season and increase stocker production. From an economic standpoint, this may be an appealing strategy, but this lengthened grazing season has unknown effects on the soil water required for fall planting, and on soil compaction from the extended grazing season.

Agricultural management practices combined with or without grazing represent two extremes in the management of available soil water. In the southern Great Plains, summer chemical fallow practices are considered water conserving. A cover crop is not grown during the summer to limit loss of water by evapotranspiration and allow soil water to accumulate. While the incorporation of summer legumes in the

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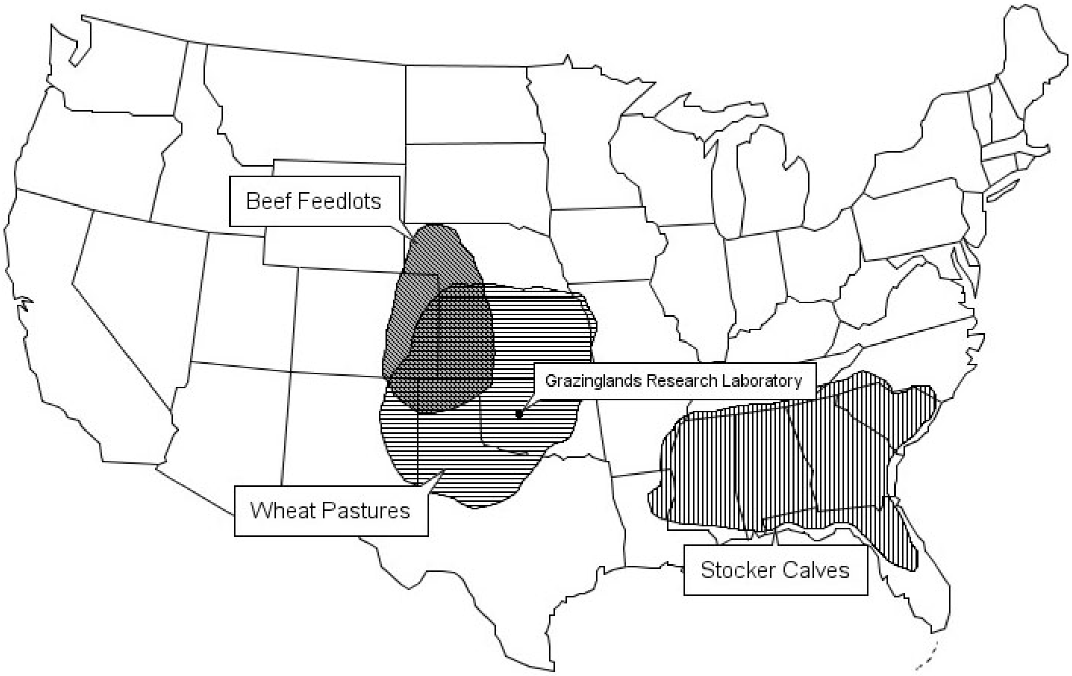

Figure 1. Study site and extent of the winter wheat belt and beef feedlots used for stocker finishing in the U.S.

rotation following winter wheat is a more aggressive water-use practice, the planting and harvesting or grazing of a summer crop utilizes soil water typically used for establishment of wheat in the fall. While overall impacts of livestock grazing on runoff and nutrient movement are documented (Blackburn, 1984), little information is available on the impacts of winter wheat systems that utilize grazed summer legumes on water resources.

Agricultural practices can impact water quality including: nutrient movement associated with animal wastes (Bitzer and Sims, 1988; Lichtenberg and Shapiro, 1997), fertilizers and pesticides (Felton, 1996; Lawrence et al., 1993), and pathogens from animal wastes (Edwards et al., 1997; Smith et al., 2001). Other research has examined agriculture's role in maintaining and enhancing water quality (Haycock and Pinay, 1993; Hill, 1996). However, information dealing with the impact of agriculture practices on in-field recharge to ground water and water resources is limited (Daniel, 1999; O'Connell et al., 1995; O'Leary, 1996).

The effect of livestock grazing on sediment transport and delivery is also well documented. A commonality exists in the conclusions of past research: high stock densities, particularly in combination with rotational grazing systems, generally increase sediment production (Naeth and Chanasyk, 1995, 1996; Pluhar, 1987; Radke and Berry, 1993; Smith, 1980; Weltz and Wood, 1986; Weltz et al., 1989). Livestock grazing can increase compaction of the soil surface, and ultimately lead to greater erosion potential by increasing bulk density and decreasing infiltration (Daniel et al., 2002; Daniel and Phillips, 2000). In addition, detrimental effects from grazing may become more significant during periods of drought or winter dormancy (Warren et al., 1986).

The objective of this project was to determine the impact of livestock grazing on runoff, sediment, and nutrient losses from pastures utilizing conventional (winter wheat (*Triticum aestivum* L.) with summer chemical fallow) and unconventional (winter wheat with the summer legume Korean Lespedeza (*Lespedeza stipulacea* Maxim)) agronomic practices.

Methods and Approach

Study Site

The study was conducted during 1998 through 2002 on four 1.6 ha pastures at the USDA-ARS Grazinglands Research Laboratory (35.53604° N, −098.054301° W) near El Reno, Oklahoma. The pastures are experimental watersheds constructed in 1976 to examine soil erosion and hydrology responses to agricultural practices and are representative of winter wheat production in the Red Prairies region of Kansas, Oklahoma, and Texas (fig. 1) (Daniel, 2001).

Soils of the study site are of the Renfrow-Kirkland series (fine, mixed, thermic Udertic Paleustoll; mean-particle size distribution: 37.5% sand, 40% silt, and 22.5% clay). Renfrow soils are typically found on crests and sideslopes, and are well drained (Fisher and Swafford, 1976). They are residuum originating from calcareous shale material. Kirkland soils are found chiefly on crests and are a moderately well-drained material that formed from the underlying shale parent material. The underlying parent material is the Permian-age Dog Creek shale, a reddish-brown shale with thin interbeds of reddish-brown siltstone (Daniel, 2002). Permeability of these soils is slow (NRCS, 1999; Fisher and Swafford, 1976).

The 30-year annual rainfall (1970 to 2000) averaged 74 cm (29 in.), with a maximum rainfall of 120.7 cm (47.5 in.) and a minimum of 60.2 cm (23.7 in.). The climate of this area exhibits an unstable balance between the humid eastern and semiarid western regions. Wet years associated with the humid eastern influence provide additional vegetative growth, and dry years associated with semiarid conditions result in reduced vegetation (Goodman, 1977).

Tillage Practices

In fall 1997, all four pastures were initially prepared by moldboard plow and repeated disking and left a year to rest. In fall 1998, the experiment began using conventional winter wheat practices (moldboard and disking). To measure the cumulative effects of grazing on soil surface properties, all subsequent planting used conservation tillage practices (wheat drill). Fertilizer loading included two 11.3 kg N/ha (40 lbs N/acre.) applications of urea: one in the fall, and another in the spring. Two management practices examined were: (1) traditional winter wheat with summer chemical fallow (WWF), and (2) winter wheat followed by summer legumes (WWSL).

Beginning in the fall of 1998, all pastures had winter grazing and spring grazeout of winter wheat. Pastures incorporating summer chemical fallow had all remaining residue cut to the height of 15 to 20 cm (6 to 8 in.), and all remaining live vegetation was killed by spraying with glyphosate (Roundup). Fallow conditions were maintained by chemical spraying to kill any live vegetation, and residue (500 to 1000 kg/ha) was left on the soil surface. Tillage practices to break up the soil such as chisel or disking were not used. Fallow conditions were maintained until wheat was planted in late September or early October. The WWSL practice utilized Korean Lespedeza as the summer legume. Lespedeza seed was broadcast into pastures in early March, while stocker cattle grazed the pastures, and the seed was worked into the soil by hoof action. Cattle were then removed from the fields and legumes grew without grazing from May until mid-July, when stockers were reintroduced to pastures. This second grazing period typically lasted until mid-September. After stockers were removed, the fields were prepared for planting for the next cycle of winter wheat.

Grazing Practices

Two grazing practices were incorporated into each management system: grazed (g) and ungrazed (u). Two 5 × 5 m fenced enclosures within each pasture served to restrict livestock grazing and were used as the ungrazed part of the paired plots (u and g) within each pasture (fig. 2). Stocker calves weighing ∼230 kg (500 lbs) were placed on the pastures during the first week of December if sufficient forage was available. Adequate forage was considered forage in large enough quantities to maintain a minimal stocking rate (0.63 to 0.8 stockers per ha). In spring, when forage availability increased due to rapid growth, additional stockers were used to increase grazing density and allowed to graze until May (table 1). Calves weighed 295 kg (650 lbs) when removed. When forage was inadequate, winter grazing was terminated early, but spring grazing resumed in the first part of March. Spring stocking density was dictated by available forage.

Rainfall Simulation

A rainfall simulator was used to determine how management practices and grazing affected runoff. The simulator was a solenoid-operated, fixed multi-nozzle field unit (Miller, 1987) attached to a lightweight, portable A-frame constructed from welded aluminum tubing. To provide uniform spray distribution during a simulation, extendable legs on the A-frame permitted the spray nozzles (30 wsq) to be elevated to a height of 3 m above the soil surface. Canvas tarps completely enclosed the unit to minimize wind effects

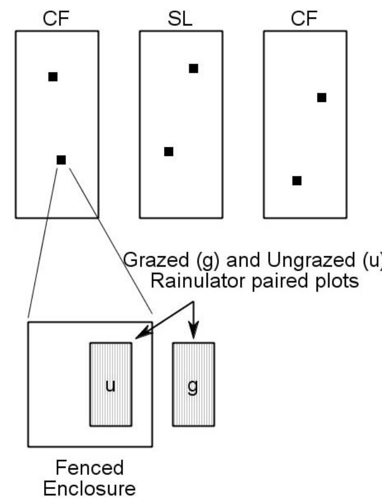

Figure 2. Layout of paired plots and rainfall simulator sites.

Table 1. Grazing history on the water resources and erosion watersheds.

	Treatment											
	Winter Wheat with Summer Legumes (WWSL)						Winter Wheat with Summer Chemical Fallow (WWF)					
	Replicate A			Replicate B			Replicate A			Replicate B		
	Date		Stocking	Date		Stocking	Date		Stocking	Date		Stocking
Year	On	Off	Density[a]	On	Off	Density[a]	On	Off	Density[a]	On	Off	Density[a]
1998	4 Dec.	−−	4	4 Dec.	−−	4	4 Dec.	−−	4	4 Dec.	−−	4
1999	11 Mar.	−−	8	11 Mar.	−−	7	11 Mar.	18 Apr.	8	11 Mar.	18 Apr.	6
	7 Apr.	18 Apr.	12	7 Apr.	18 Apr.	14						
	6 Aug.	9 Sept.	10	6 Aug.	9 Sept.	10						
2000	13 Mar.	12 May	3	13 Mar.	11 May	3	13 Mar.	12 May	9	13 Mar.	12 May	9
2001	27 Mar.	15 May	4	27 Mar.	15 May	4	27 Mar.	11 May	5	27 Mar.	7 May	5
	15 July	31 July	12									
2002	1 Apr.	10 May	4	1 Apr.	−−	4	1 Apr.	−−	6	1 Apr.	−−	6
	−−	−−		22 Apr.	−−	8	22 Apr.	−−	10	22 Apr.	6 May	10
	−−	−−		6 May	13 May	18	10 May	13 May	14			
	11 July	−−	4	11 July	−−	4						
	17 July	1 Aug.	11	17 July	−−	11						

[a] Stocking density in head/pasture (stockers/1.6 ha).

Table 2. Averaged water analysis of water used in rainfall simulator. Samples were collected from sample cups in the plots during simulation.

	2000		2001	
	Mean	SD	Mean	SD
pH	8.29	0.13	8.28	0.10
Conductivity (mhos/cm)	1264	22	982	53
Total dissolved solids (mg/L)	842	14	656	36
Nitrate-N (mg/L)	0.48	0.05	0.29	0.05
Bioavailable phosphorus (µg/L)	6.34	6.07	9.44	7.13
Water-soluble phosphorus (µg/L)	9.29	7.13	4.94	5.47

on spray patterns. Three square-spray nozzles, spaced 1 m apart, were mounted to spray downward onto the study plot. The spray time interval was controlled with a variable-speed electric motor, cam lobe (which dictated length of spray time), and micro switches, according to specifications presented by Miller (1987). Water for rainfall simulations was hauled to the site using a 1,890 L (500 gal) water tank and trailer and pumped at a pressure of 30 kPa. Analysis of the water is provided in table 2.

Plot preparation involved mowing sites to a uniform height (5 cm, 2 in.) and removing the mown vegetation and residue. Rectangular steel frames (1.5 × 3 m) were set into the soil to a depth of 8 cm (3 in.) to direct runoff to a collecting point. Runoff was collected at the bottom (long end) of the frame and transferred to a large plastic storage container by a bilge pump. The discharge capacity of the pump was great enough to prevent back flooding and ponding of plots during simulation runs. The collection container was equipped with a pressure transducer, which measured water levels in the storage container. Measurements were transmitted and recorded in millivolts using a Campbell Scientific CR-10 data logger interfaced to a laptop computer via an RS-232 cable. Millivolt readings were converted to water volumes using a conversion equation calibrated for the equipment. Calibration was done by putting 18.9 L (5 gal) in the catchment barrel with the inserted pressure transducer interfaced with the CR-10 and laptop computer, measuring the millivolt changes produced by the transducer with each addition of water, and equating the change to the measured volume.

The rainfall intensity of each run was measured using four 500 mL collection containers installed at predetermined positions within the frames. The rainfall intensity produced by the simulations was calibrated by placing 36 rainfall collection containers in a grid within the 1.5 × 3 m plot frame and applying thirteen 15 min calibration runs under the given parameters (fig. 3). After each calibration run, the volume of water collected in each container was measured and recorded for each grid location. The nozzles produced higher volumes of rainfall in the central portion of the frame compared to the edges. An average rainfall of 10.3 cm/h (std. dev. 0.5 cm/h) was determined. Rain droplet size was determined using the flour method outlined in Laws and Parsons (1943) at various locations under the nozzles. An average drop diameter of 2.7 to 2.8 mm was recorded. Rainfall simulations were conducted in September of 2000 and 2001, after cattle were removed from WWSL pastures and the WWF pastures had been in fallow from May through September, prior to fall planting.

Using precipitation records collected at the research station at El Reno, Oklahoma, rain simulator runs were

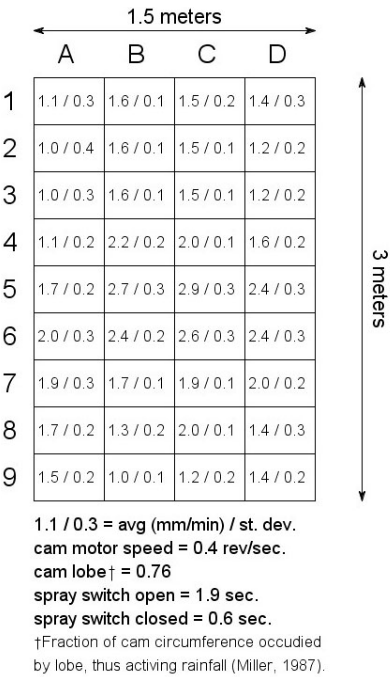

Figure 3. Distribution of simulated rainfall within the 1.5 × 3 m plot frame and equipment settings for the simulation runs.

designed to simulate the intense, short-duration storms that occur in the southern Great Plains during late summer. To provide a realistic representation of these storms and their impact on runoff, the runs simulated short, intense (10 cm/h or 4 in./h) rainfall events. Evaluation of the precipitation records demonstrated that the greatest storm intensity occurred generally in the first 15 min, so a 15 min duration was chosen to best represent late summer storms. Parameters obtained from each simulation run included time to initial runoff (T_i) and runoff after 15 min of rainfall (V_{15}). Each simulation run was continued until runoff had been observed for at least 15 min so water samples could be collected. Plots were not pre-wetted.

Water Analysis

Runoff samples were collected at three time increments: initial runoff (0 min), 5 min after initial runoff, and 15 min after initial runoff. Water samples were collected and stored at 4°C in 500 mL polypropylene bottles and analyzed for nitrate-N (NO_3-N), bioavailable phosphorus (BAP), water-soluble phosphorus (WSP), and sediment yield. The NO_3-N analysis was conducted utilizing standard cadmium-reduction procedures (USEPA, 1979). Bioavailable phosphorus was determined using colorimetric analysis by the molybdate-blue/ascorbic acid method (Sharpley et al., 1991). Filtrate from 0.45 micron filters was analyzed for WSP using colorimetric determination by ascorbic acid reduction (Murphy and Riley, 1962). Sediment yields were measured after filtering runoff sample through a 47 mm dia. 0.2 micron pore filter, drying for 24 h at 105°C, and weighing the residue after cooling.

Statistical Analysis

Side-by-side positioning of paired grazed and ungrazed plots was used on each pasture (fig. 2). This allowed a comparison to be made at a single site that shared the same

Table 3. ANOVA for runoff (L) after 15 min of rainfall.

Source	d.f.	V_{15} MS	F	P
Agricultural practices (AP)	1	684	4.8	0.07
Error $_{(AP)}$	6	143	--	--
Grazing (G)	1	2286	12.7	0.01
AP × G	1	385	2.1	0.20
Error $_{(G)}$	6	189	--	--
Total	15			
Model	4	839	2.5	

experimental management but different treatments, and the overall effect of treatments could be evaluated regardless of potential effects of in-field variability and variability between pastures caused by soil type, vegetation cover, and landscape position. Data were analyzed within a replicated (n = 4), completely randomized, split-plot design with the main effects being agricultural management practice (WWF and WWSL) and grazing treatment (g and u) in the split plot (Sokal and Rohlf, 2000). Replicates used in this analysis were a combination of individual pastures and years of simulations, which allowed the effects of time and space to be encompassed within the effect and error terms. Significant and main interactions effects were tested with Fisher's protected least significant difference.

RESULTS

ANALYSIS OF VARIANCE

A significant difference (P = 0.07) was noted between the effects of agricultural practice (table 3), and a significant difference was recorded between grazing treatments (P = 0.01). No interaction (P = 0.20) was recorded between agricultural practices and grazing. Since sediment, nitrogen, and phosphorus amounts were based on runoff volumes, analyses of variance were only applied to V_{15}. Nutrient and sediment data were averaged for each management type and treatment.

RUNOFF

Average differences in runoff generation indicate that the summer chemical fallow practice generated runoff earlier in the simulated rainfall event than the summer legume practice. The relationship for initial runoff time was T_i grazed < T_i ungrazed, and V_{15} grazed > V_{15} ungrazed was determined for runoff volumes. Time to generate runoff from grazed WWF and WWSL treatments occurred after only 6 and 8 min, respectively (table 4). The ungrazed WWF practice took 15 min to generate runoff, while the ungrazed WWSL management practice required 23 min.

Differences in runoff related to management practice indicate that WWF had a greater percentage of rainfall lost as runoff than WWSL, and differences in runoff related to grazing suggested that grazed plots lost a larger percentage of runoff than ungrazed (table 4). Mean runoff from the chemical fallow (gWWF) practice was 71% of applied rainfall. Grazed winter wheat with summer legumes (gWWSL) had a loss to runoff of 23%. Alternatively, ungrazed plots (uWWF and uWWSL) lost 12% and 5% of the applied rainfall, respectively.

SEDIMENT YIELD

The WWF management practice generated average sediment yields of 196 kg/ha, while the WWSL strategy produced 29 kg/ha (table 4). Grazing produced nearly 3 times more sediment than the ungrazed treatment (163 vs. 62 kg/ha). The largest sediment loads were from gWWF plots, which generated 284 kg/ha. The ungrazed summer chemical fallow management (uWWF) had the second-highest sediment load with 107 kg/ha, more than double that of either WWSL management practice. Grazed summer legume plots averaged 42 kg/ha, while uWWSL plots averaged 16 kg/ha.

NUTRIENTS

Nutrient trends in runoff for this study were similar to runoff and sediment yields. The WWF management practice had the highest levels of NO_3-N (64 kg/ha), BAP (199 g/ha), and WSP (25 g/ha) (table 5). Grazed treatments had higher levels of NO_3-N (62 kg/ha), BAP (33 g/ha), and WSP (224 g/ha) than ungrazed plots. Plots utilizing the gWWF strategy had the greatest levels of nitrate-N (124 kg/ha), while the three remaining strategies had much lower levels of nitrate-N movement (<5 kg/ha).

The relationship of WSP in runoff was similar to that of BAP. The gWWF treatments had the greatest movement of WSP (380 g/ha), while the gWWSL treatment had the second highest level (67 g/ha) (table 5). Water-soluble phosphorus in runoff from ungrazed plots ranged from 15 to 18 g/ha.

Bioavailable phosphorus in runoff ranged from 2 to 38 g/ha (table 5). The WWF practice had 2 times more BAP in runoff (25 g/ha) than the WWSL (14 g/ha). Grazed plots had 5 times more BAP than ungrazed plots (33 vs. 7 g/ha). The greatest concentration of BAP in runoff was generated

Table 4. Runoff volumes (V_{15}), time to initial runoff (T_i), and sediment yields as affected by management practices and grazing treatments.

Management[a]	Treatment	V_{15} Liters Mean	V_{15} Liters SD	V_{15} Percent Mean	V_{15} Percent SD	T_i (min.) Mean	T_i (min.) SD	Sediment (kg/ha) Mean	Sediment (kg/ha) SD
WWF	All	19	17.6	42	37.3	11	8.5	196	230.0
WWSL	All	8	10.0	14	18.2	16	12.6	29	50.8
All	Ungrazed	4	5.3	8	12.4	19	12.6	62	127.4
All	Grazed	21	16.8	47	34.2	7	2.5	163	220.4
WWF	Ungrazed	5	5.6	12	13.8	15	10.3	107	172.5
WWF	Grazed	29	18.1	71	28.5	6	2.1	284	256.1
WWSL	Ungrazed	3	5.1	5	10.7	23	14.0	16	18.1
WWSL	Grazed	13	11.3	23	20.2	8	2.8	42	69.5

[a] WWSL = winter wheat with summer legumes.
WWF = winter wheat with summer chemical fallow.

Table 5. Nitrate-N, water-soluble phosphorus (WSP), and bioavailable phosphorus (BAP) quantities as impacted by management practices and grazing treatments.

Management[a] and Treatment		NO_3-N (kg/ha) Mean	SD	WSP (g/ha) Mean	SD	BAP (g/ha) Mean	SD
WWF	All	64	145.5	199	307.7	25	41.9
WWSL	All	1	1.27	41	54.1	14	27.9
All	Ungrazed	3	3.9	17	28.6	7	11.5
All	Grazed	62	146.1	224	295.2	33	45.7
WWF	Ungrazed	4	5.1	18	24.6	11	15.3
WWF	Grazed	124	192.5	380	357	38	55.4
WWSL	Ungrazed	1	1.8	15	33.8	2	3.0
WWSL	Grazed	1	1	67	59.5	27	36.2

[a] WWSL = winter wheat with summer legumes.
WWF = winter wheat with summer chemical fallow.

by gWWF plots (38 g/ha). The gWWSL strategy had the next highest level with 27 g/ha. Ungrazed plots produced BAP yields that ranged from 2 to 11 g/ha.

Discussion

Runoff from high intensity, short duration, simulated rainfall events provided an indicator of potential water loss from pastures in response to a combination of management and grazing practices. Results from rainfall simulator trials showed that three times as much precipitation was lost as runoff under summer chemical fallow management than when managing a double-cropped summer legume after wheat, which runs counter to conventional wisdom. Earlier research on these pastures using resistance to penetration and bulk density measurements showed that grazing increased compaction levels (Daniel and Phillips, 2000). Observation of soil cores taken before the rainfall simulations showed a 1 to 2 cm hard dry crust, which was too hard to penetrate with a handheld cone penetrometer. It is speculated that the long dry summers produced a surface crust on the summer fallow plots, which restricted water infiltration. However, infiltration occurred after a period of wetting. Alternatively, increased root density and residue cover of the summer legume apparently protected the ground surface, reduced crusting effects, and promoted infiltration. Results also showed increased water movement from plots under summer chemical fallow, indicating that this practice may not be as successful at conserving water as originally believed.

Examination of available aboveground biomass by pastures show the greatest biomass yields on all pastures in the fall of 1998 following moldboard preparation in 1997 (table 6). All pastures showed a decrease in biomass yield in the fall over the first year, and biomass levels remained low after fall planting. Overall, grazed paddocks, whether chemical fallow or summer legume, showed lower yields of wheat forage for winter grazing than ungrazed management practices. While large volumes of runoff were recorded for summer fallow pastures, it is believed that surface crusting is a temporary phenomenon. Even so, farmers using conservation tillage practices should incorporate chisel or disk tillage to break up the surface crust, preferably in the early summer to catch rainfall.

Runoff is generally water not available for plant or crop use. While such losses are considered undesirable, understanding the mechanism of increased runoff associated with summer management practices and late summer storms can lead to possible mitigation suggestions that ultimately lead to some benefits. Placement of surface water impoundments and catchments below potentially high runoff areas may capture most of this runoff and provide storage for immediate or future use. While these structures are primarily designed for sediment capture, their role could be expanded to serve as a water supply. Rapid runoff can fill these water storage facilities, prevent impairment of downstream water quality, and provide some relief to livestock during late summer dry periods. Other benefits include capturing surface water to allow recharge of local ground water aquifers, thus improving water supplies for base flow of rivers, streams, and lakes during periods of little or no rain.

Sediment yield showed that grazed pastures have greater potential for erosion than pastures without grazing (table 4), a commonly reported result (Blackburn, 1984; Weltz and Wood, 1986; Weltz et al., 1989). It was also found that the chemical fallow management practice produced higher sediment yields than the summer legumes. In Oklahoma, the fallow practice includes shredding the remaining residue, which remains on the ground surface. In some cases, just before fall planting, the ground surface is chiseled, plowed, or disked to break up the surface crust, while sometimes the wheat is drilled into the soil with no preparation. Generally, summer legumes have a better and more complete coverage of plant residue on the ground surface and grow with a rhizome root structure unlike that of winter wheat. This reduces the loss of soil by wind and surface water.

Nutrient losses were directly related to runoff amounts. Since water is the nutrient-carrying medium, the management practice with the greatest loss of runoff will also have the highest amount of nutrient loss. This also affects downstream water quality with the introduction of chemicals to streams. Breaking up the surface crust with disking or chisel plowing will allow greater infiltration, but may also cause greater sediment loads. It is important to note that all applied practices were well within guidelines for soil loss for best management practices for the soils studied. The T value (Renfrow-Kirkland series) for USLE is 7258 kg/ha (5 tons/acre).

Table 6. Available aboveground biomass (dry wt kg/ha) of established fall wheat crop. Ungrazed values are averages of two subsamples from within the two enclosures for each pasture. Grazed values are averages from five subsamples from each pasture.

Sample Date	WWF Replicate A Grazed	WWF Replicate A Ungrazed	WWF Replicate B Grazed	WWF Replicate B Ungrazed	WWSL Replicate A Grazed	WWSL Replicate A Ungrazed	WWSL Replicate B Grazed	WWSL Replicate B Ungrazed
	Winter Wheat with Summer Chemical Fallow (WWF)				Winter Wheat with Summer Legumes (WWSL)			
29 Dec. 1998	1690	2518	1565	1434	2717	2330	1795	--
16 Nov. 1999	222	446	348	1000	231	282	128	267
4 Dec. 2000	269	149	291	191	300	266	254	536
9 Jan. 2002	609	682	661	590	531	1036	374	1065
4 Nov. 2002	115	639	108	1058	217	1105	148	793

CONCLUSIONS

The southern Great Plains relies on the stocker production industry for much of its economic livelihood. However, economic necessity should not adversely affect environmental conditions or impact natural resources. Livestock grazing leads to changes in soil properties, resulting in increased erosion and offsite water quality concerns. This study suggests that summer management practices like chemical fallow can impact the amount of precipitation lost as runoff after a hot, dry summer and result in the opposite of its intended effect. Temporary crusting of the soil appears to exist and is compounded by grazing activity. Storm events at the end of a dry summer are typically fast-moving, intense storms. In such situations, the practice of summer fallow following grazing of winter wheat causes a loss of 71% of this late summer precipitation as runoff, compared to incorporating grazed summer legumes (gWWSL) into pasture management. Grazing of pasture planted to annual forages can result in heightened runoff and erosion, compared to ungrazed plots.

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